

## Patent Abstracts of Japan

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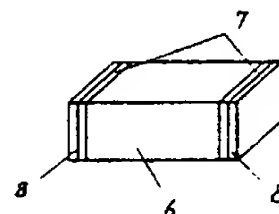
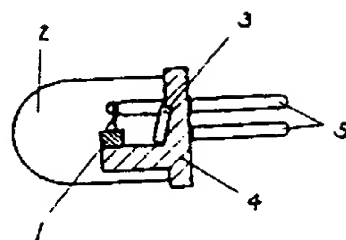
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APPLICANT : MATSUSHITA ELECTRIC IND CO LTD;

INVENTOR : WADA MASARU;

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TITLE : SEMICONDUCTOR LASER DEVICE



**ABSTRACT :** PURPOSE: To enable the manufacture of a device at a low cost by a method wherein a silicon film whose thickness is  $7/100 \sim 8/100$  of a wavelength is coated on an aluminum film coated on an end face whose thickness corresponds to one-fourth of a wavelength, which are sealed with a transparent plastic resin of a refractive index of 1.3~1.6.

CONSTITUTION: A semiconductor laser element 1 and a photodiode 3 are buried in a transparent plastic resin 2 in place of a cap provided with a window glass. In this process, an aluminum film  $7/4$  as thick as a wavelength and a silicon film  $8/7/100 \sim 8/100$  as thick as a wavelength are laminated on both the end faces of the passivation film of the laser element 1, whereby the refractivity of both the end faces decreases to about 32% when the element 1 is buried in the resin of a refractive index of 1.3~1.6. Therefore, a laser oscillating threshold current and a differential quantum efficiency of the element 1 are made equal to those of a conventional element, so that the element 1 does not vary in characteristic. By these processes, a package can be decreased in cost, a divergence angle can be controlled, and the element is also excellent in heat dissipation and hermetic sealing.

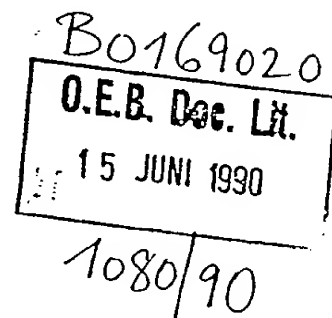
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(202) 223-8130



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TUC3 Room temperature continuous wave vertical cavity surface emitting GaAs injection lasers

K. TAI, R. J. FISCHER, C. W. SEABURY, N. A. OLSSON, T. D. C. HUO, Y. OTA, A. Y. CHO, AT&T Bell Laboratories, Murray Hill, NJ 07974.

There has been a surge of interest in vertical cavity surface emitting laser diodes (VCSELs).<sup>1-4</sup> The ability of room temperature cw operation is crucial to the practical use of such devices. We report room temperature cw operation of GaAs VCSELs. The VCSEL shown in Fig. 1 was grown by molecular beam epitaxy and, starting from the Si doped GaAs substrate, consisted of an *n*-type  $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$  etch stop followed by an *n*-type twenty-two-pair  $\text{Al}_{0.1}\text{Ga}_{0.9}\text{As}/\text{AlAs}$  semiconductor distributed Bragg reflector (DBR), an  $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}/\text{GaAs}$  (0.5- $\mu\text{m}$ ) double heterostructure active region, a five-pair *p*-type  $\text{Al}_{0.1}\text{Ga}_{0.9}\text{As}/\text{Al}_{0.7}\text{Ga}_{0.3}\text{As}$  semiconductor DBR, a 450- $\text{\AA}$   $\text{Al}_{0.7}\text{Ga}_{0.3}\text{As}$  phase matching layer, and finally a 100- $\text{\AA}$  GaAs heavily *p*-doped contact layer.

The *p*-mirror termed hybrid metal DBR here uses constructive interference between the reflection from a five-pair semiconductor DBR and metal layer. The room temperature lasing threshold occurred at 40 mA dc (22-kA/cm<sup>2</sup> current density neglecting the lateral current spreading). An optical power in excess of 1 mW was measured. The external slope quantum efficiency was  $\sim 2\%$ . The emission spectrum below the threshold showed a broad structure (reflecting the broad gain spectrum) with the superimposition of an  $\sim 4$ -5- $\text{\AA}$  sharp spike due to the cavity resonance enhanced emis-

Pour le titre du livre OFC '90/TUESDAY AFTERNOON/11  
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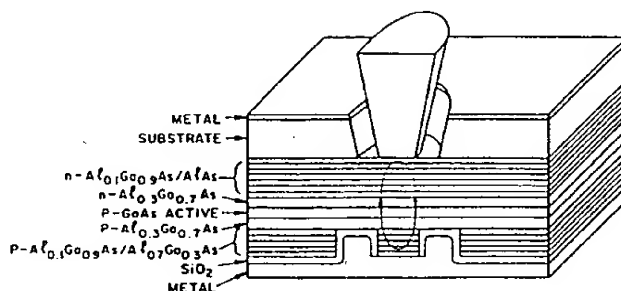
sion. Above the threshold, the width of the cavity mode reduced to 1  $\text{\AA}$  (spectrometer resolution-limited), and its intensity dominated. The usual exponential temperature dependence of threshold current [ $I_{th} \sim \exp(-T/T_0)$ ] was measured for the VCSEL, and  $T_0$  was found to be 115 K in the temperature range of 15-50°C. The emission of the VCSEL was found to be omnidirectional below the threshold. An abrupt change in the far field pattern occurred at the threshold, where a symmetric 2-D Gaussianlike profile appeared with an emission (full) angle of  $\sim 5^\circ$ .

Figure 2 shows the results (part of the bit pattern and an eye diagram) of a pseudorandom signal modulation of the VCSEL at a 500-Mbit/s data rate. The optical spectrum of the random signal VCSEL emission was essentially the same as that of the cw emission with a more than 25-dB side-mode suppression ratio measured with a 1- $\text{\AA}$  resolution.

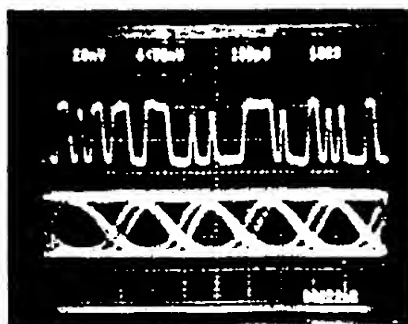
Summarizing: Room temperature cw single-longitudinal and single-transverse-mode vertical cavity surface emitting lasers were constructed with an emission power  $> 1$  mW.

1. T. Sakaguchi, F. Koyama, and K. Iga, *Electron. Lett.* **24**, 928 (1988).
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4. A. Ibaraki *et al.*, in *Technical Digest, Seventh International Conference on Integrated Optics and Optical Fiber Communication*, Kobe, Japan (1989), paper 18B1-3.

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TUC3 Fig. 1. Cross-sectional representation of the VCSEL consisting of the substrate an *n*-type twenty-two pair DBR reflector, a GaAs/ $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$  double heterostructure active region, and a hybrid *p*-type metal DBR reflector.



TUC3 Fig. 2. Eye diagram (bottom) and random data stream (top) at 500 Mbit/s.

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